Third Report
to the
National Radio Systems Committee

AM IBOC DAB Laboratory and Field Testing

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iBiquity Digital Corporation

8865 Stanford Boulevard, Suite 202
Columbia, Maryland 21045
(410) 872-1530

20 Independence Boulevard
Warren, New Jersey 07059
(908) 580-7000

Executive Summary

This report to the National Radio Systems Committee contains the results of comprehensive laboratory and field tests of iBiquity Digital Corporation's AM IBOC DAB system. These test were designed to assess both the performance of the AM IBOC system in comparison to existing analog AM performance and the compatibility of the IBOC system with existing analog operations. The test results demonstrate that iBiquity's AM system offers significant benefits that cannot be matched by analog AM radio and that IBOC can be introduced without harmful interference to existing analog AM operations. The information in this report supports the conclusion that IBOC meets the needs of the broadcast industry, the consumer electronics industry and the listening public.

The test program summarized in this report was conducted in accordance with the NRSC's IBOC DAB test procedures. The tests included both laboratory and field tests designed to assess the performance of the digital system and to determine whether digital implementation would impact existing analog operations. Objective compatibility laboratory tests were conducted by Xetron, Inc. Objective performance laboratory tests were conducted by the Advanced Television Technology Center. Field tests were conducted by iBiquity personnel in the presence of NRSC observers. Audio samples from the field and the laboratory were subjectively evaluated at Dynastat, Inc.

The test program established conclusively that the AM IBOC system will offer a significant improvement in audio quality over existing analog AM. The tests provided a comparison of AM IBOC with analog FM in which the subjective evaluators rated AM IBOC equivalent to or close to FM in all test categories. The tests also established the superiority of the digital system when compared to analog AM. The subjective evaluators consistently scored digital above analog for all 300 sound samples in the subjective evaluation. Moreover, in a direct comparison of analog and digital in good quality analog conditions in the field tests, digital consistently outscored analog.

The improved audio quality is accompanied by strong digital durability in the presence of co-channel and adjacent channel interference as well as channel impairments associated with the AM band. Operating in either the core or the enhanced mode, the digital system outperformed analog in the presence of co-channel interference as well as first and second adjacent channel interference. The digital system also outperformed analog in the presence of impulse noise at several levels and either outperformed or matched analog performance in the presence of other channel impairments. This combination of improved audio quality and enhanced durability from the digital system will provide AM listeners with a significantly improved listening experience.

The test program also determined that AM IBOC can be introduced without a harmful impact on existing analog AM operations. The compatibility test program examined the impact of the introduction of IBOC on host analog operations as well as the analog operations of first adjacent, second adjacent and third adjacent stations. The tests

demonstrated that in the majority of cases, the introduction of IBOC will not have a noticeable impact on analog operations.

Based on the improved performance offered by the AM IBOC system and the compatibility of the system with existing analog operations, iBiquity encourages the NRSC to promptly endorse this new technology and support the quick implementation of IBOC as the digital radio system for the United States.

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This third report to the National Radio Systems Committee ("NRSC") contains the results of laboratory and field tests of iBiquity Digital Corporation's ("iBiquity") AM IBOC DAB system. This report supplements iBiquity's first two reports that detailed test results on the FM IBOC system. This report details the results of tests designed to assess the performance of the digital AM system and the compatibility of the digital AM system with existing analog AM operations. These AM test results demonstrate the digital system will provide an upgrade to existing analog AM service, allowing broadcasters to use AM for an expanded range of formats and services. At the same time, the results show that the introduction of AM IBOC will not cause harmful interference to existing analog service in the majority of circumstances. Thus, the NRSC should endorse the AM IBOC system and encourage the prompt approval of this technology.

I. Introduction

The iBiquity AM system presented in this report is an outgrowth of the LDR and USADR systems that were tested in 1999 and evaluated by the NRSC in 2000. The general system characteristics and attributes are well known by the NRSC. As was the case for iBiquity's FM tests, the AM system tested and presented in this report used the AAC audio compression technology. iBiquity will use iBiquity's audio compression technology in commercial IBOC equipment, which will not impact any of the test results presented in this report. A detailed AM system description can be found in Appendix A. Except for the nighttime all-digital results reported in Section II, all results presented in this report were derived from operation of the IBOC system in the hybrid waveform mode.

A. System Overview

The iBiquity AM IBOC system operates in two modes: hybrid and all-digital. In the hybrid mode, digital audio and data information is transmitted simultaneously underneath and adjacent to the analog transmissions. In the all-digital mode, the power level of the digital carriers, located in the area previously occupied by the analog signal, is increased to improve robustness. The digital signals are comprised of OFDM waveforms that are placed directly underneath and on either side of the analog signal.[1]

An audio codec is used to compress the digital audio stream to fit within the limited AM channel bandwidth. The codec apportions the audio into "core" and "enhanced" streams, and the system assigns the streams to different parts of the spectrum. The "core" stream carries monaural digital quality audio and the "enhanced" stream carries, at a broadcaster's option, enhanced fidelity and/or stereo. The system allocates the "core" stream to the most robust portions of the channel and the enhanced to the remaining spectrum. Figures 1 and 2 illustrate the hybrid and all-digital spectra. In the more detailed system description contained in Appendix A, the "core" stream is referred to as the "primary" carriers. The secondary and tertiary carriers comprise the "enhanced" stream.

[1] See Appendix A at Sections 5.3 and 5.4 for further details.

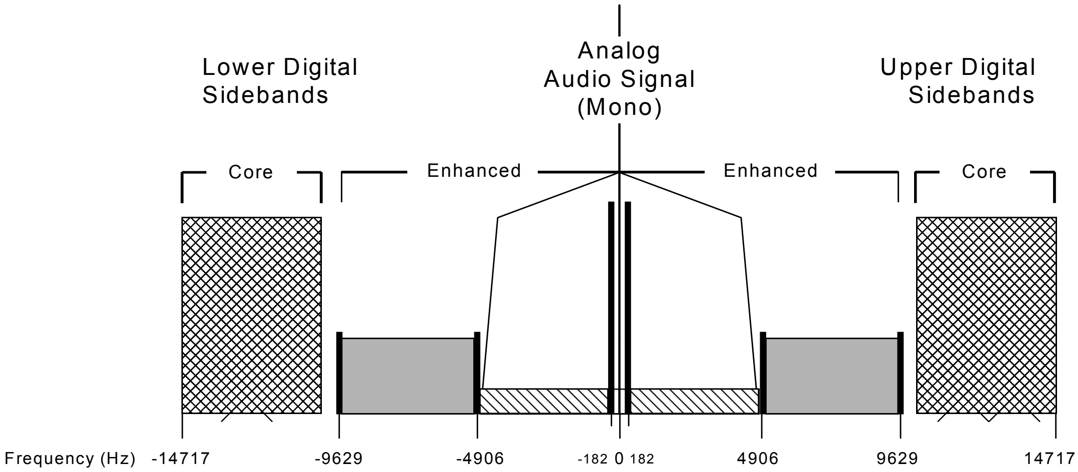


Figure 1 - AM IBOC Hybrid Waveform Spectrum

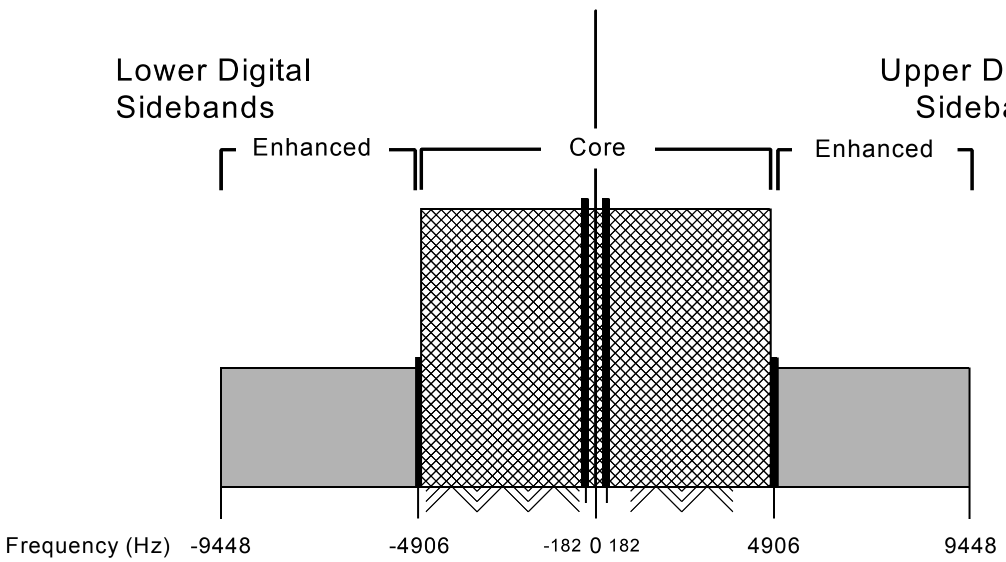


Figure 2 - AM All-Digital Waveform Spectrum

The "core" and "enhanced" streams are combined in the receiver to provide the highest audio quality when receiving conditions permit. As interference increases or the receiver approaches the edge of coverage, the receiver seamlessly transitions to monaural audio quality. In the hybrid mode, a second transition occurs to analog when the digital signal fails.

B. The Test Program

All of the AM tests were conducted pursuant to the NRSC's AM laboratory and field test procedures developed in 2001. Those procedures were designed to assess both the digital performance of the system and the system's compatibility with existing analog AM operations. The tests were conducted using the same receivers selected for the main channel FM tests. The NRSC selected these receivers to represent the range of receiver characteristics available in the marketplace. For example, the NRSC chose the Pioneer receiver to represent high-end, selective receivers. The Sony receiver was chosen as a representative of more economical, less selective receivers. The test receivers are listed in Table 1 below.

Type	**Manufacturer**	**Model No.**
Original Equipment Auto	Delphi	PN 09394139
Aftermarket Auto	Pioneer	KEH-1900
Home Hi-Fi	Technics	SA-EX140
Portable	Sony	CFD-S22

Table 1 – List of Test Receivers

The objective laboratory performance tests were conducted at the Advanced Television Technology Center ("ATTC") in Alexandria, Virginia. The objective laboratory compatibility tests were conducted at Xetron Corporation ("Xetron") in Cincinnati, Ohio. The NRSC and its observers were afforded open access to both labs at all times, and an NRSC representative actively participated in both labs' work. Each lab recorded the results from its tests independently from iBiquity. Appendix B contains a report detailing the Xetron test bed, the Xetron test procedures, and the AM compatibility laboratory test results. The ATTC test bed, procedures and results are presented in Appendices H-K. In addition to these objective measurements, the ATTC and Xetron recorded audio samples for both the digital and analog receivers for each test conducted. The audio samples were subsequently sent to Dynastat, Inc. ("Dynastat") for subjective evaluation. The NRSC actively participated in the design of the test environment at Dynastat. Dynastat's laboratory was open to the NRSC, which conducted an on-site inspection to validate the test environment. Appendix E contains a description of the subjective evaluation methodology used for the AM tests. Appendix F describes the procedures used at Dynastat. Appendix G details the results of the subjective evaluation.

Field testing comprised the final component of the test program. The NRSC's field test procedures identified specific conditions to be tested, the test stations to be used and the drive routes to be followed. Field tests were conducted at three commercial and one experimental AM radio stations. All tests were conducted using iBiquity personnel and equipment. An NRSC observer witnessed all field tests. Appendix C contains a detailed description of the field test equipment and procedures. The field test stations are listed in Table 2 below. Appendix D contains maps detailing the test locations for the compatibility field tests and the results for the field performance tests.

IBOC Station	Location	Frequency (kHz)	Class	Format	Analog Power (Day)	Analog Power (Night)	Digital Power (kHz)
WTOP	Washington DC	1500	A	News	50 kW	50 kW	2.9
WWJ	Detroit, MI	950	B	News	50 kW	50 kW	2.9
KABL	Oakland, CA	960	B	Adult Standard	5 kW	5 kW	0.29
WD2XAM	Cincinnati, OH	1660 (day) 1650 (night)	Exp	Various	10 kW	1 kW	0.58(d) 0.058 (n)

Table 2 - Field Test Stations

In addition, Table 3 lists the stations used for host and adjacent channel compatibility testing:

IBOC Station	Desired Station	Location	Frequency	Class	Format	Analog Power (Day)	Digital Power (Day)	Compatibility Test
WTOP		Washington DC	1500 kHz	A	News	50 kW	2.9 kW	Host
	WARK	Hagerstown, MD	1490 kHz	C	Talk	925 W		1st Adjacent
	WDAS	Philadelphia, PA	1480 kHz	B	Gospel	5 kW		2nd Adjacent
	WFAI	Salem, DE	1510 kHz	B	Gospel	2.5 kW		1st Adjacent
	WLPA	Lancaster, PA	1490 kHz	C	Sports	600 W		1st Adjacent
	WTTR	Westminster, MD	1470 kHz	B	Various	1 kW		3rd Adjacent
WWJ		Detroit, MI	950 kHz	B	News	50 kW	2.9 kW	Host
	WKHM	Jackson, MI	970 kHz	B	Talk	1 kW		2nd Adjacent
	WEOL	Elyria, OH	930 kHz	B	News	1 kW		2nd Adjacent
KABL		Oakland, CA	960 kHz	B	Adult Stndrd	5 kW	290 W	Host
	KESP	Modesto, CA	970 kHz	B	Sports	1 kW		1st Adjacent
	KAHI	Auburn, CA	950 kHz	B	Various	5 kW		1st Adjacent
	KCTY	Salinas, CA	980 kHz	B	Spanish	10 kW		2nd Adjacent
WD2XAM		Cincinnati, OH	1660 kHz	Exp	Various	10 kW	580 W	Host

Table 3 - Host and Adjacent Channel Compatibility Field Test Stations

As was the case with the FM results previously submitted to the NRSC, iBiquity has concentrated its analysis on the field test results obtained from the test program. In the course of its consideration of the FM IBOC results, the NRSC concluded the field tests provided a more accurate view of the real world impact of IBOC. iBiquity continues to support this view and has focused on the field tests, particularly for the compatibility test results.

C. Subjective Component of NRSC Test Program

Consistent with the FM tests, the chosen subjective test methodology, the Absolute Category Rating Mean Opinion Score ("ACRM"), was used for iBiquity's AM tests. In the ACRM methodology, subjects judge the sound samples they hear on an individual basis. For each sample, they use their internal frame of reference to judge the audio quality. Participants subjectively evaluate the audio samples, assigning each to one of five categories: Excellent; Good; Fair; Poor; Bad. Answers from the participants are later translated into numerical values (5 through 1) for the purpose of computing mean opinion scores from individual scores. In each ACRM experiment, participants were presented with approximately 200 sound samples that differed on several dimensions. They were asked to give a statement of "overall quality" for each sample, taking into consideration the variety of audio dimensions or impairments that were present. Before starting the experiment, participants were familiarized with the range of impairments they would encounter. The subjective evaluation lab screened participants for their ability to hear small impairments and/or differences in audio quality. Only responses from participants who were trained and who passed the screening test were included in the data that is presented in this report.

iBiquity's FM test report detailed the results of the "MOS Interpretation Study". That study was conducted for the purpose of providing context for scores derived from ACR experiments. The study identified the point at which an average listener would no longer listen to a radio signal. This point was slightly different for each genre: 2.0 for Rock, 2.1 for Classical Music, and a 2.3 for speech. When interpreting subjective evaluation results from the AM compatibility tests, this average "turn off" point should continue to be considered as one measure of consumer acceptability.

II. Results

A. Audio Quality[2]

The performance tests repeatedly demonstrated that improved audio quality is a key advantage of the AM IBOC system. iBiquity's AM IBOC system will deliver FM quality sound and will dramatically improve the AM listening experience. The test program results provided several analyses, all of which confirmed that the digital system will improve audio quality.

Throughout the subjective evaluation program, impairment-free analog FM sound samples, recorded at ATTC through the Delphi receiver, were included as "high anchors" during the evaluation of the AM analog and digital samples. These analog FM sound samples were selected because they provided excellent anchors for the AM tests. The inclusion of these analog FM samples also permitted a direct comparison of digital AM audio quality to existing analog FM. As Figure 3 below illustrates, listeners rated AM IBOC statistically the same as analog FM with Rock, Classical and Voiceover samples. With Speech, listeners rated AM IBOC close to analog FM or "FM-like".

[2] The IBOC DAB equipment used in the tests incorporated the AAC audio compression technology rather than the iBiquity audio compression technology that the final system will use. The codec used in the test equipment has no impact on the NRSC's ability to assess the compatibility of the system with existing analog operations or the performance of the system in the face of impairments and interference. However, the NRSC agreed that the unimpaired audio quality test, which looks at audio fidelity in a clean channel environment, is designed to assess the performance of the codec and would be inappropriate to conduct until iBiquity's compression technology is incorporated in the system. Therefore, no data related to *unimpaired* audio quality is available from this test program.

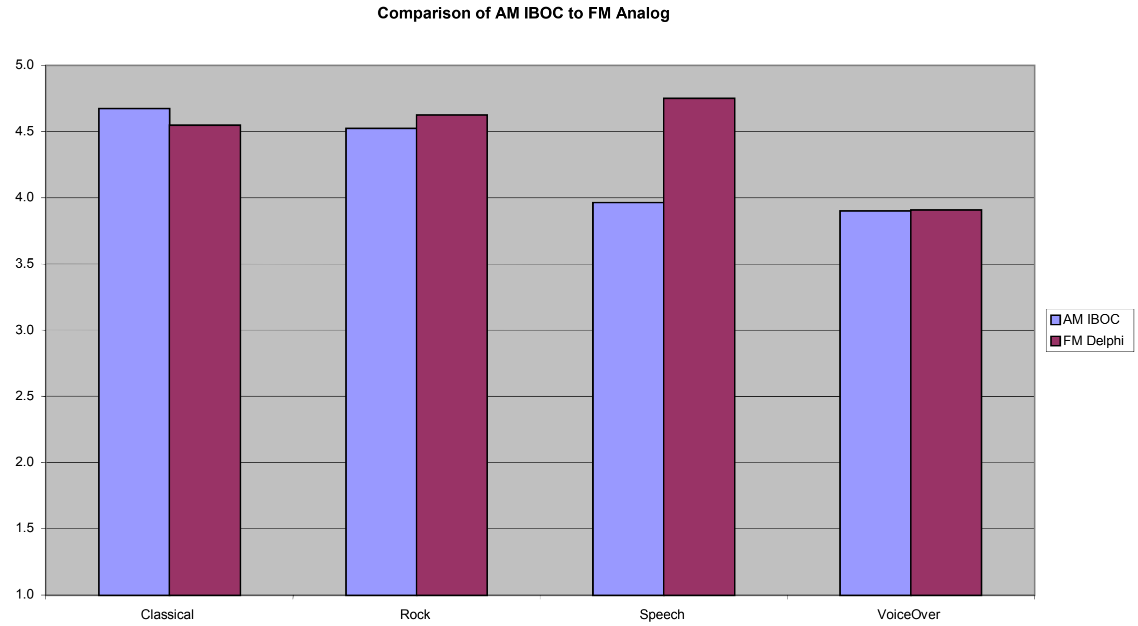
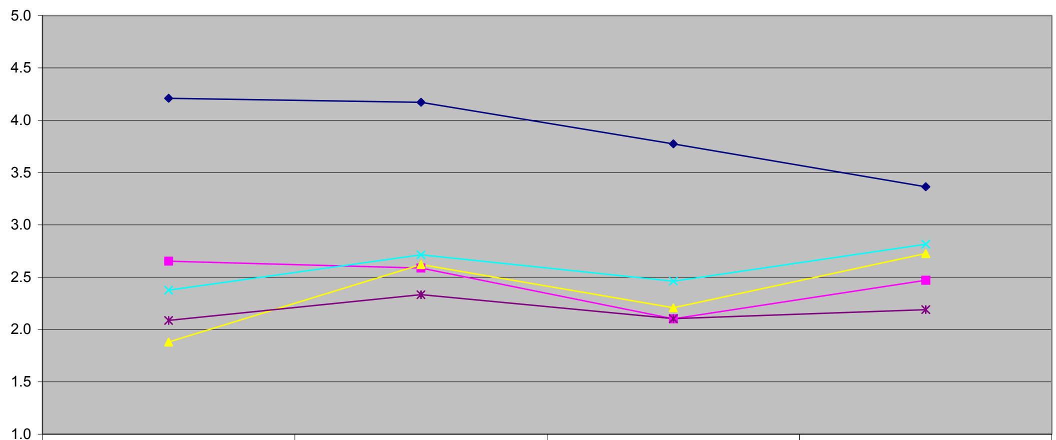


Figure 3 - Comparison of AM IBOC and FM Analog Audio

The subjective evaluation program also allowed for direct comparisons of AM IBOC and analog AM. As Figure 4 below illustrates, a compilation of all the performance sound samples indicates the subjective evaluators consistently preferred AM IBOC to analog AM. The AM IBOC performance subjective evaluation program involved 60 listeners evaluating over 300 sound samples. Figure 4 aggregates the performance of the IBOC, and each of the four analog receivers in all conditions. The performance tests examined the receivers' operations in the presence of co-channel, first adjacent channel, and second adjacent channel interference, impulse noise and a variety of other channel impairments typically found in the AM band. For each of the four test genres (Rock, Classical, Speech and Voiceover), digital was judged to be far superior to analog.

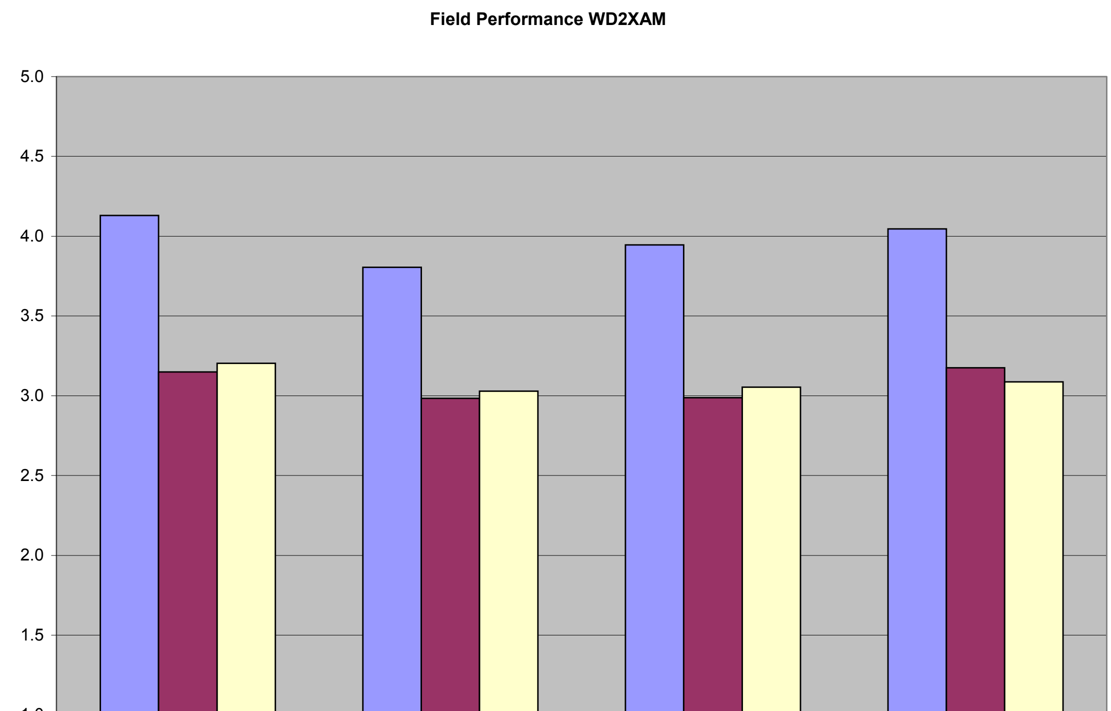
Overall Lab Performance (Tests B, C, and D)



	Classical	Rock	Speech	VoiceOver
IBOC	4.2	4.2	3.8	3.4
Delphi	2.7	2.6	2.1	2.5
Pioneer	1.9	2.6	2.2	2.7
Technics	2.4	2.7	2.5	2.8
Sony	2.1	2.3	2.1	2.2

Figure 4 - Performance of Digital and Analog Receivers
Aggregating All Field Test Conditions

iBiquity also conducted a separate subjective evaluation of audio samples from the field to compare analog and digital audio quality in an area with strong signals and good analog performance. Audio samples from WD2XAM were used for this experiment because (i) that station has no daytime co- or adjacent channel interferers and (ii) iBiquity was able to select higher quality audio than is found on many commercial AM stations. In this test, audio was recorded at set distances 2.5, 5, 7.5, 10, 15 and 20 miles from the transmitter on six separate radials around the station. Audio samples from the IBOC, Delphi and Pioneer receivers were recorded at each of the 36 locations, producing 108 sound samples for subjective evaluation. As Figure 5 below illustrates, the subjective evaluation of these samples demonstrates that listeners preferred IBOC to both the Delphi and Pioneer receivers, even in areas with good quality analog reception. This provides direct evidence that listeners prefer the audio quality of AM IBOC to analog AM.



	0° Radial	90° Radial	180° Radial	270° Radial
IBOC	4.1	3.8	3.9	4.0
Delp	3.2	3.0	3.0	3.2
Pion	3.2	3.0	3.1	3.1

Figure 5 - Field Performance of WD2XAM in Strong Signal Conditions

These tests demonstrated conclusively that listeners will judge the AM IBOC system as an improvement over analog AM. Listeners will find AM digital sound to be comparable to analog FM and a significant improvement over the audio quality of analog AM.

B. Service Area

The field test program used four stations to assess the coverage of the digital system. The tests demonstrated that the IBOC system provided an extensive digital service area. The AM IBOC system operates at approximately 5% of the power of analog AM. As Figure 6 below illustrates, even at this level, the IBOC system was able to provide consistent daytime digital coverage to the 2 mV/m contour of the test stations. In some areas, coverage extended beyond the 1 mV/m contour.

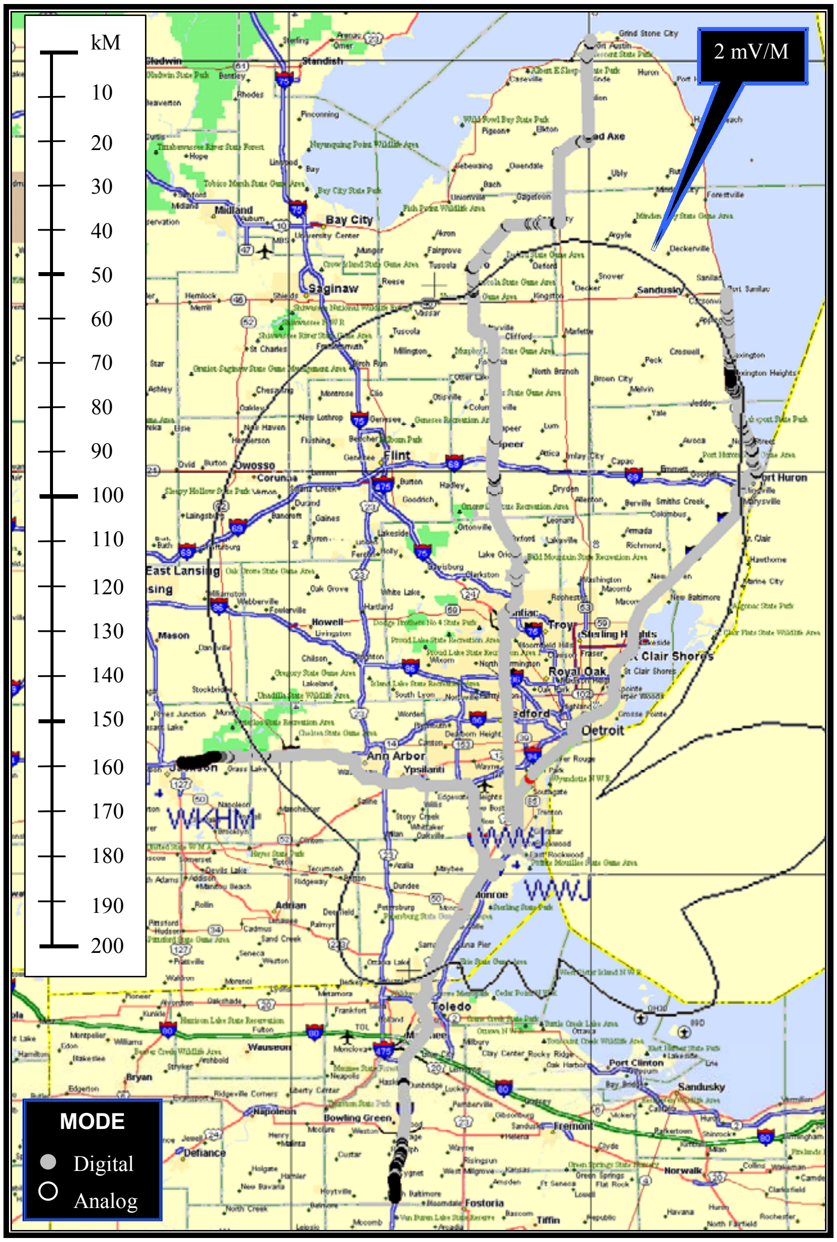


Figure 6 - Field Performance WWJ (Hybrid/Daytime)

The field test stations were selected to examine the impact of various environments on the IBOC system. The tests emphasized (i) adjacent channel interference; (ii) urban, suburban and rural conditions; and (iii) grounded conductive structures. As can be seen from the maps in Appendix D, the test program demonstrated consistent daytime coverage for all test stations. Overall, the results indicated the IBOC system covers each station's area of analog listenership. Even though there may be certain listeners on the periphery that fall outside the digital coverage area, the system's blend-to-analog feature ensures that IBOC coverage is never less than existing analog coverage.

Due to the extreme levels of interference experienced at night in the AM band, the digital system provided a more restricted nighttime service area. The system provided digital service to the 10 mV/m contour. In some cases, digital coverage extended to the 5 mV/m contour. This level of coverage ensures that IBOC provides digital service to the station's city of license and its core listening area. As is the case with daytime coverage, the blend to analog feature ensures that all existing listeners will continue to receive the station's programming. Nighttime coverage will improve significantly with implementation of the all-digital system. iBiquity conducted an additional test using WTOP to determine the service area of the all-digital system. WTOP presents a particularly difficult situation for the hybrid system because the nighttime adjacent channel interference levels are in excess of the hybrid mode digital carriers. The increased power level of the all-digital mode significantly increases the nighttime service area. For this all-digital test, the system operated at 40 kW. As Figure 7 illustrates, the all-digital system operating at night is able to provide coverage to the 2 mV/m contour, with coverage extend beyond the 0.5 mV/m contour in some areas.

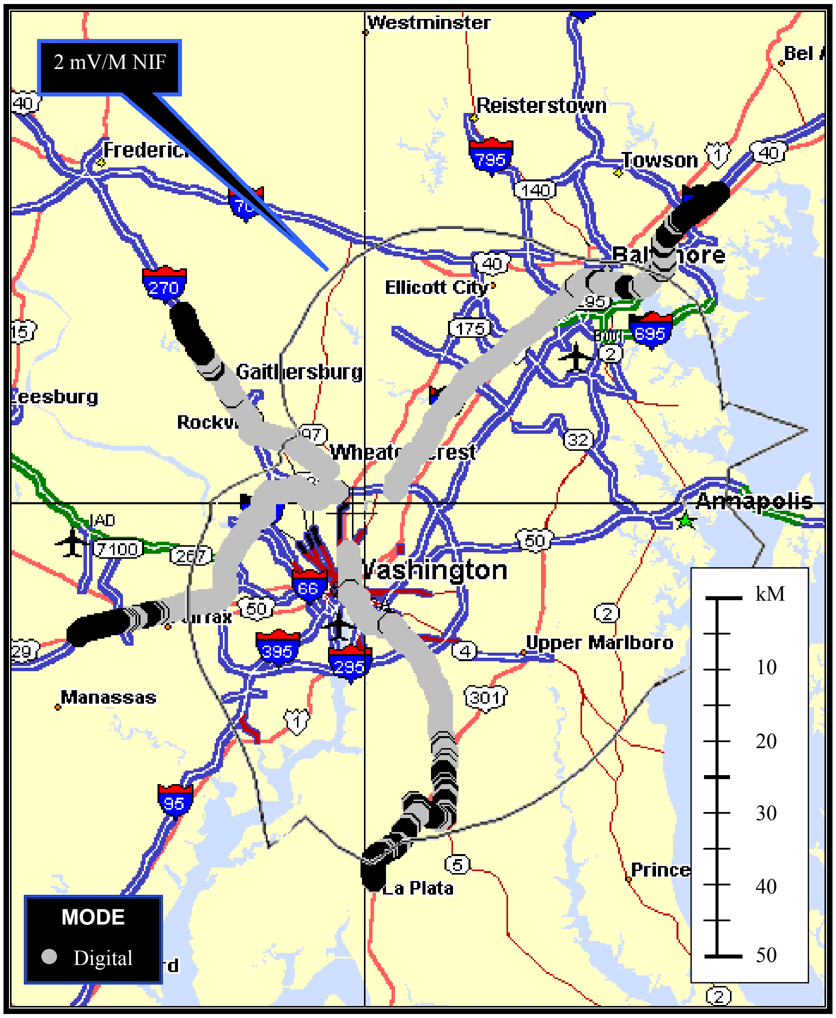


Figure 7 - Field Performance WTOP (All-Digital/Night)

C. Durability

The test results demonstrated that the digital system's durability either matches or, in the majority of cases, significantly exceeds that of analog AM in a variety of interference and impairment conditions. The tests included co-channel and adjacent channel interference, impulse noise and other impairments. All of the durability tests were conducted by adding the interference or impairment to both the digital and analog signals. Audio samples from the digital system just prior to the point of transition from enhanced to core and from core to analog were compared against the analog signal at that same level. The result is a comparison with analog quality at a point before digital suffers any degradation.

The co-channel test showed IBOC provides strong resistance to this interference. As Figure 8 illustrates, in ACRM tests IBOC outscored the analog receivers' performance with co-channel interference for the digital system operating in either the core or the enhanced mode.

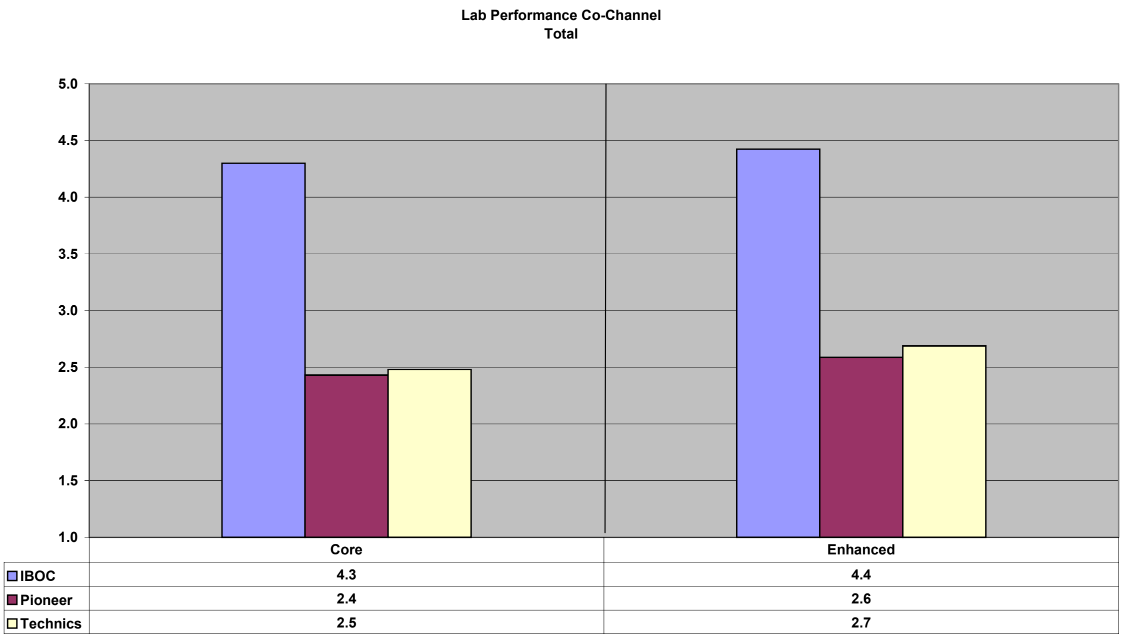


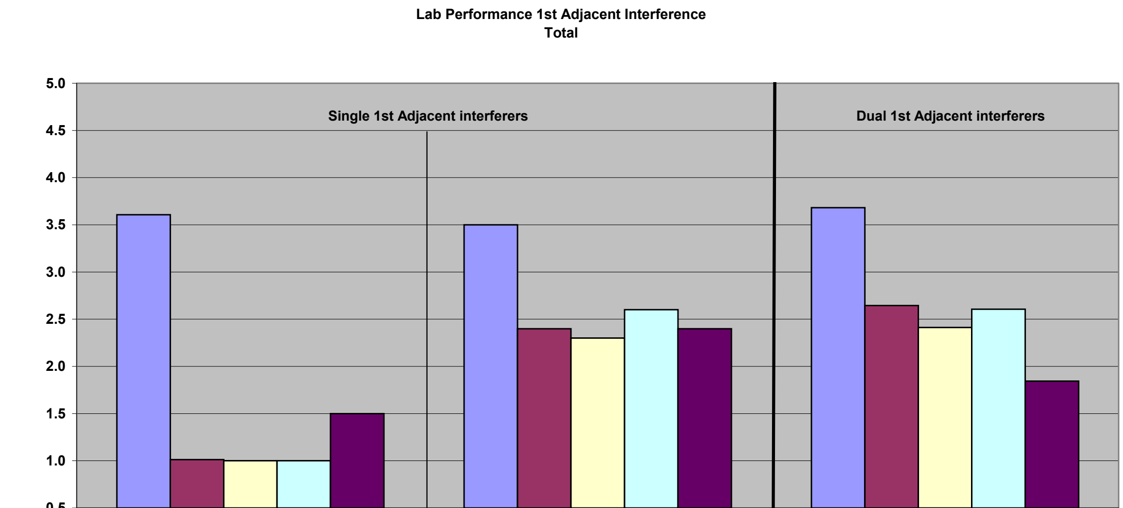
Figure 8 - Lab Performance with Co-Channel Interference

Unfortunately, due to the lack of daytime adjacent channel interference for the field test stations, only a limited amount of field performance data was obtained. Nonetheless, the results, summarized in Table 4, showed that the digital system provides resistance to first adjacent channel interference comparable to the Pioneer and exceeding the Delphi with Speech and exceeding both analog radios with Voiceover.

Condition	**Speech**			**Voiceover**		
	IBOC	Delphi	Pioneer	IBOC	Delphi	Pioneer
1st Adjacent Interference	2.7	1.2	2.6	3.7	1.4	2.8

Table 4 - Field Performance with Moderate First Adjacent Interference

Laboratory tests confirmed these benefits of the digital system. As Figure 9 illustrates, the digital system consistently outperformed analog with single and dual first adjacent channel interferers. The tests obtained these results with the digital system in both the core and the enhanced modes.[3]



	Core with 1st Adj. Interferer	Enhanced with 1st Adj. interferer	Core with dual 1st adjacent interferers
IBOC	3.6	3.5	3.7
Pioneer	1.0	2.4	2.6
Technics	1.0	2.3	2.4
Delphi	1.0	2.6	2.6
Sony	1.5	2.4	1.8

Figure 9 - Lab Performance with First Adjacent Interference

The tests also showed the digital system offers resistance to second adjacent interference comparable to and in many cases exceeding analog performance. The field tests indicated digital performance is comparable to analog durability in the presence of strong and moderate second adjacent channel interference. As Figure 10 illustrates, the lab tests indicated the digital system provided superior durability with second adjacent interference even when second adjacent channel interference is combined with first adjacent channel interference.

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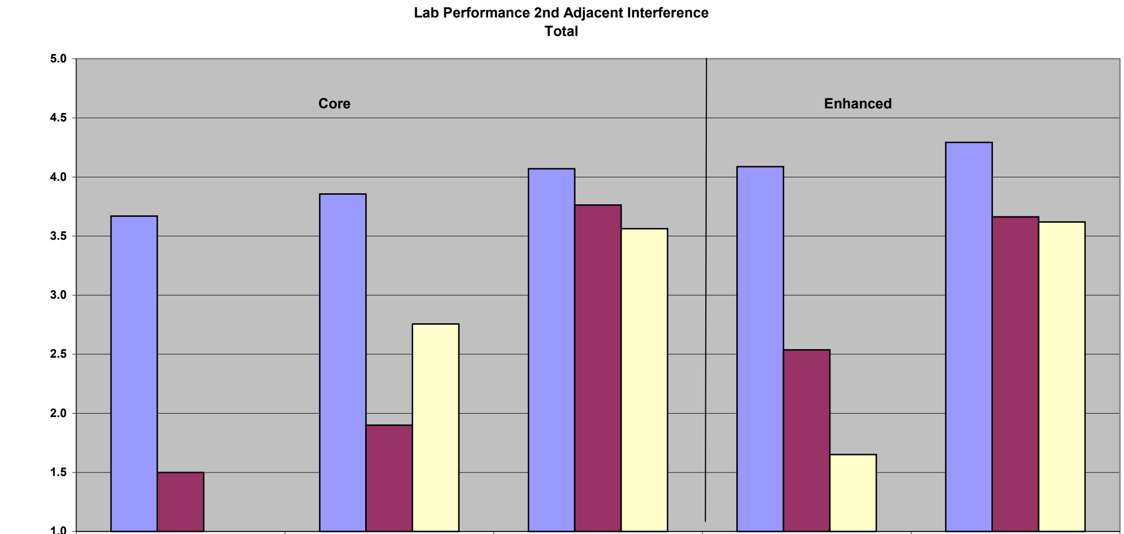
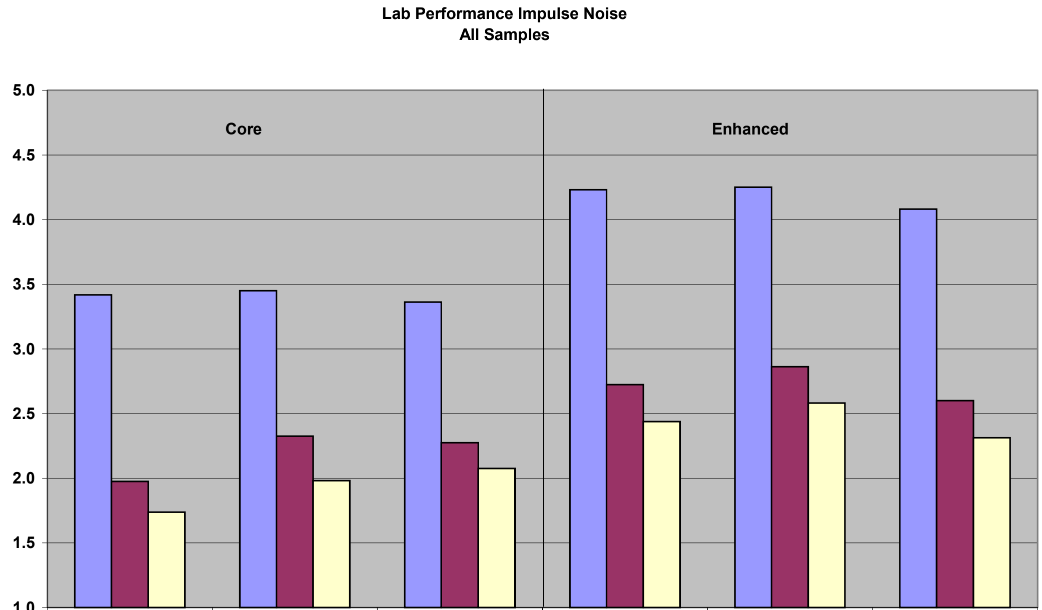
3 Because the enhanced mode test was conducted at a higher analog signal level than the core mode test, the analog samples scored higher in the enhanced test.



	Core with 2nd Adj. interferer	Core with 2nd Adj. interferer and 1st Adj interferer @+6dB	Core with dual 2nd Adj. interferers (Upper 2nd @ 0dB)	Enhanced with 2nd Adj. interferer	Enhanced with dual 2nd Adj. interferers (Upper 2nd @ 0dB)
IBOC	3.7	3.9	4.1	4.1	4.3
Sony	1.5	1.9	3.8	2.5	3.7
Technics	Failure	2.8	3.6	1.7	3.6

Figure 10 - Lab Performance with Second Adjacent Channel Interference

The digital system also provides robustness against channel impairments. For example, the digital system exhibited superior resistance to impulse noise when compared with existing analog performance. As Figure 11 illustrates, when operating in either the core or enhanced mode, the digital system outperformed analog for all three rates of impulse noise tested.



	120	510	1800	120	510	1800
IBOC	3.4	3.5	3.4	4.2	4.3	4.1
Delphi	2.0	2.3	2.3	2.7	2.9	2.6
Sony	1.7	2.0	2.1	2.4	2.6	2.3

Figure 11 - Lab Performance with Impulse Noise (in Hertz)

Figure 12 confirms, even when first adjacent channel interference is added to the impulse noise, the digital system continues to outperform existing analog receiver performance.

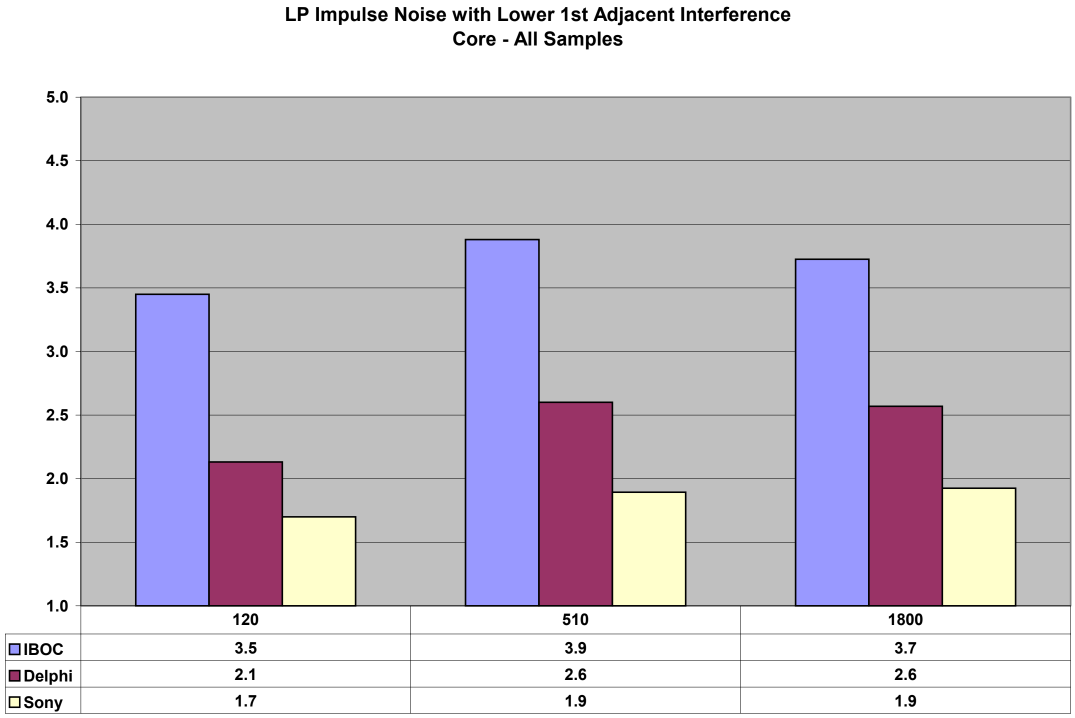


Figure 12 - Lab Performance with Impulse Noise (in Hertz) and 1st Adjacent Interference

With other impairment conditions, the digital system exhibited robustness comparable to or exceeding that of analog. As Table 5 illustrates, for each condition shown, digital outperformed at least one of the two analog radios. Because these auto receivers exhibited better overall performance than the portable or home HiFi receiver, iBiquity believes the improved digital performance would be even more apparent if compared against the other analog receivers.

Condition	Speech			Voiceover			Popular		
	IBOC	Delphi	Pioneer	IBOC	Delphi	Pioneer	IBOC	Delphi	Pioneer
EMI	3.5	3.1	2.6	2.8	2.8	1.7			
Fade	3.6	3.4	2.9						
Night/Skywave	3.1	3.0	2.9				4.1	3.7	3.4
Power Line Interference	3.5	3.4	2.9	4.1	2.8	2.8			
Power Line Re-Radiation	3.5	3.4	3.2						

Table 5 - Field Performance with Impairments

Overall, the digital system offers significant improvements in durability when compared to analog in all interference and most impaired conditions. The IBOC signal is receivable under these conditions even with its relatively low power compared to analog. These results and the test program do not address an additional benefit of the digital system. The time diversity between the analog and digital signals ensures that the system does not experience the complete loss of signal that is associated with analog AM when driving under bridges and power lines. The test program was not designed to examine this system feature, but the blend and time diversity features ensure that the signal blends from digital to analog when there is loss of the digital signal. Although the blend may result in reception of lower quality analog rather than the digital signal due to a signal fade from an overhead obstruction, the lower quality analog signal is far superior to the complete loss of signal typically associated with today's analog AM.

D. Acquisition Performance

Laboratory tests confirmed the functionality of the blend element of the system design. The laboratory tests revealed that the system acquired the signal and delivered listenable audio in 300 milliseconds on average. This is comparable to typical analog receiver signal acquisition.

E. Auxiliary Data Capacity

Currently FM subcarriers are used to deliver ancillary data for many applications, however, no ancillary data services are available with analog AM. IBOC will provide AM broadcasters the flexibility to deliver data services.

iBiquity anticipates that initial IBOC receivers will support program associated data applications. iBiquity expects service offerings and digital receiver features to expand rapidly. The type of data services available to consumers will depend on broadcasters' decisions regarding audio quality and data capacity. The hybrid AM system will support a limited amount of data (up to 1 kbps) when a broadcaster is using the highest possible AM digital audio quality. Broadcasters also will have the ability to increase data throughput by reducing the amount of audio throughput. Reducing audio throughput from 36 kbps to 20 kbps will increase data capacity to 16 kbps. This is accomplished by substituting the enhanced audio within data. Broadcasters will have the flexibility to adjust digital audio quality, providing flexibility in capacity tradeoff decisions. Table 6 summarizes broadcaster flexibility in tailoring their audio and data throughput based on the needs of their listeners in all modes of implementation:

	Stereo Digital Audio (36 kbps)	**Mono Digital Audio (20 kbps)**
Data	< 1 kbps	16 kbps
Audio	36 kbps	20 kbps

Table 6 – IBOC AM Data Throughput Rates

As the table suggests, there is an inherent trade-off between audio quality and wireless data transmission rates. With IBOC and other digital systems, the higher the wireless data throughput rates, the lower the audio throughput. The flexibility to make these trade-offs will be at the discretion of radio broadcasters.

A feature that is unique to IBOC is additional data throughput that is available when the audio codec does not require the entire throughput. Known as “opportunistic” data, this capacity is provided by iBiquity’s audio compression technology, which is capable of identifying situations where the audio/speech content is not making full use of the bandwidth allocated to audio services. In these situations, the codec is capable of reallocating the bandwidth for data services. This throughput is in addition to the data rates in the table above.

F. Behavior as Signal Degrades

The iBiquity AM system has two points at which blending may occur. The system operates at both 36 kbps and 20 kbps. As the system detects errors in the 16 kbps layer that comprises the enhanced mode, the system blends to the 20 kbps core mode. Similarly, as errors are detected at the 20 kbps level, the system blends to analog. The blend function serves separate purposes in these cases. The enhanced carriers are more susceptible to noise than and are not as powerful as the core carriers. The AM digital system was designed to maximize the area where the enhanced carriers are available. Thus, wherever possible, the system provides 36 kbps sound. At the same time, in conditions where the lower power enhanced carriers are corrupted by noise or interference, the system incorporates the blend to the core carriers to minimize digital artifacts without the need to blend fully to analog. The blend to analog serves a separate function. This prevents a sudden loss of reception at the edge of digital coverage. Instead of a sudden loss, the system blends to analog, which provides a more graceful degradation than is typically associated with digital systems.

iBiquity conducted a variety of blend tests to assess the functionality of each mode incorporated in the AM IBOC system. Although mode transition is a particularly important feature of iBiquity’s system, it is a function, not a “condition”. The goal of these tests was to verify that the mode transition function did not diminish the listener’s enjoyment of the audio. The tests examined the transition from the enhanced mode to the core mode, from enhanced directly to analog and from core to analog. As can be seen in greater detail in Appendix G, the mode transitions did not degrade the listening experience.

G. Stereo Separation

The AM IBOC system offers stereo separation during the enhanced mode of operation. The ATTC conducted a supplemental test to assess the stereo separation found in the presence of Additive White Gaussian Noise. The tests were structured to assess stereo separation objectively and subjectively using sample audio. As is described in greater detail in Appendix K, expert observation indicated the IBOC system operating in the enhanced mode maintained full stereo separation at all times with both music and speech samples.

H. Flexibility

Flexibility was addressed in iBiquity's August 2001 report on the FM IBOC system. Because the FM and AM systems were designed as a comprehensive solution, the flexible attributes discussed in the earlier report apply to both FM and AM operations.

I. Host Compatibility

The test program confirmed that, in the majority of situations, the introduction of AM IBOC will not cause harmful interference to the analog operations of the host station. For purposes of this discussion, "host" is used to mean the station that has adopted hybrid IBOC broadcasting to allow for simultaneous analog and digital broadcasts. In many cases, the introduction of AM IBOC has no noticeable impact on the host analog signal. With certain receivers, the introduction of IBOC will introduce a low level of background noise when listening in a relatively clean environment, such as near the tower in an open field or in the lab. The test results indicate, however, even in these situations, the AM IBOC signal will not harmfully impact listenership because the analog audio quality remains above the level at which the average listener would change the station.

The field tests indicated any potential impact is receiver dependent. As Figure 13 below illustrates, listeners to the auto receivers were the least likely to hear any change in the analog broadcast as a result of the introduction of IBOC.

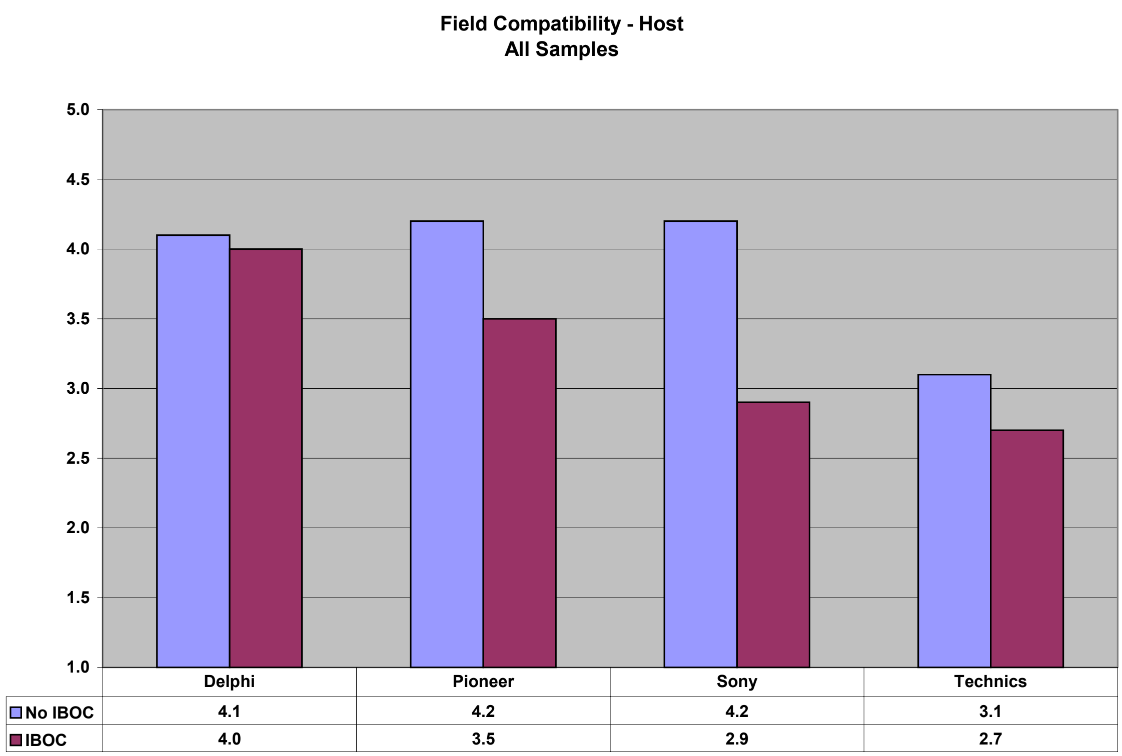


Figure 13 - Field Host Compatibility Results

The Delphi receiver was highly resistant to any impact from the introduction of IBOC. The Pioneer receiver, while demonstrating some potential impact, retained good performance even after the introduction of IBOC. The Technics receiver also demonstrated a fairly small potential impact from the introduction of IBOC, even though home HiFi receivers are not known for AM analog performance. This helps explain the lower analog scores for the Technics receiver before the introduction of IBOC. The Sony receiver demonstrated the greatest potential for any impact from the introduction of IBOC. Unlike the other three radios, the Sony has a low cost filter, which passes adjacent channel stations and noise in weak signal environments. Moreover, the Sony receiver front end is not as robust to off-channel interference, which likely had a significant impact on the results obtained in the field. Based on the price differential of the receivers, the degradation of performance is not surprising. As a result of these design limitations needed to reduce costs, the Sony radio performs well in strong signal areas but performs poorly under weak signal conditions due to its susceptibility to adjacent channel stations and noise. The IBOC compatibility tests, conducted within close proximity to the station transmitter, represent a worst-case scenario for the Sony radio where it is likely to have its best analog performance. Outside this high signal level area, the analog signal level degrades and any potential impact from IBOC would be masked. It is important to note that even using the least selective receiver in the closest area to the IBOC signal did not result in a subjective evaluation score that would cause listeners to change the station. Moreover, some analog radios will not even work in these areas due to front-end overload.

The laboratory tests confirmed these results from the field. Table 7 below contains the objective results from the laboratory host compatibility tests. iBiquity's internal testing has indicated an audio signal-to-noise (SNR) ratio degradation of less than 6 dB is barely noticeable to average listeners. Therefore, these results indicated the introduction of IBOC would not significantly reduce the receiver SNR. The auto receivers have less than a 6 dB change in SNR. Even though the Technics and Sony receivers had a greater impact, the level of impact is not sufficient to degrade the listening experience to cause listeners to change the station.

Receiver	IBOC OFF	IBOC ON
Delphi	45.1	44.3
Pioneer	45.5	39.8
Sony	40.8	33.7
Technics	47.5	38.5

Table 7 - Lab Host Compatibility (WQP SNR in dB)

The subjective evaluation of the laboratory host compatibility test results confirmed this interpretation of the objective results. For the auto receivers, there was no meaningful difference between the scores of the host analog signal without IBOC and with IBOC. Figure 14 below illustrates that in the aggregate the subjective evaluators found no meaningful impact on the auto receivers from the introduction of IBOC.

Similarly, for the home HiFi receiver, the introduction of IBOC had an insignificant potential impact. Only the Sony radio exhibited a larger potential impact. Even in this case, however, any impact would not cause the average listener to turn off the radio.

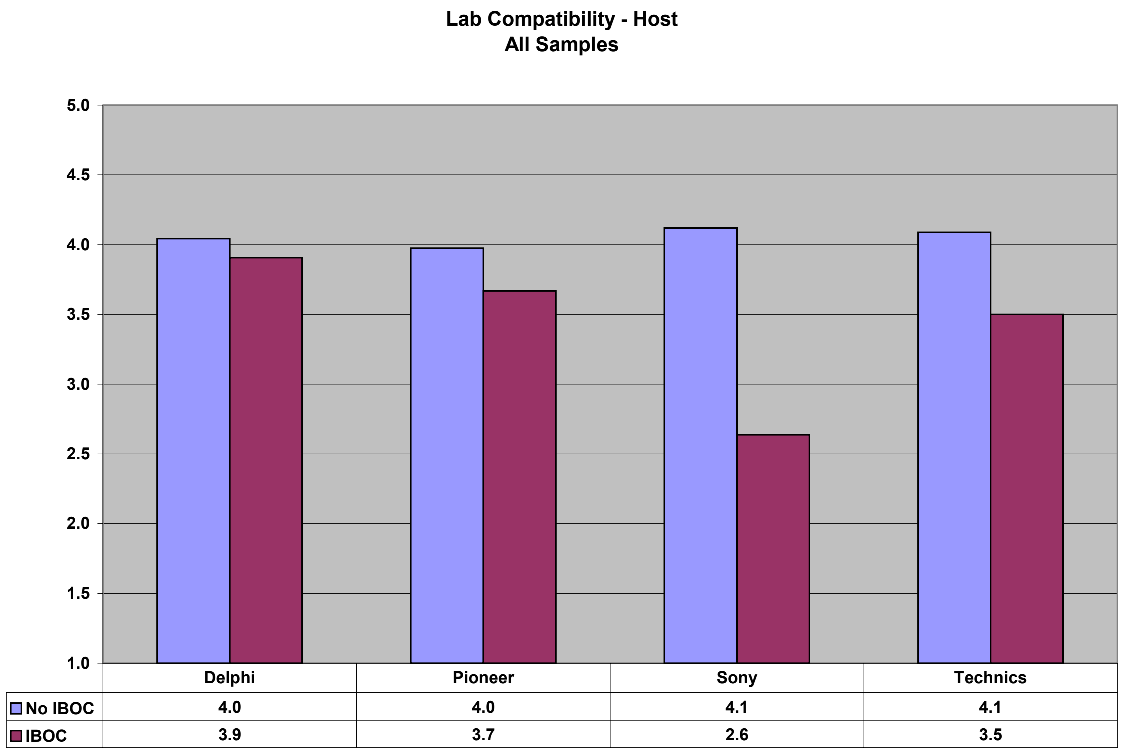


Figure 14 - Lab Host Compatibility

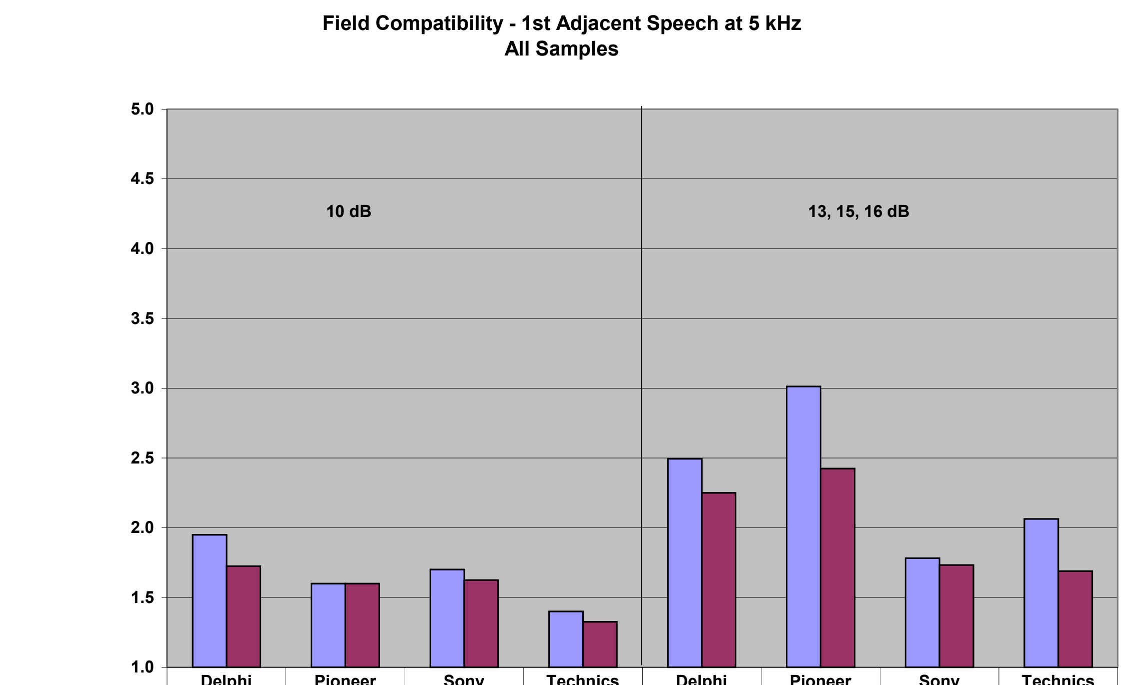
Based on the foregoing, the NRSC should conclude IBOC can be introduced without harmful interference to host analog operations in the vast majority of cases.

J. Non-Host Compatibility

1. First Adjacent Compatibility

The field and laboratory results demonstrated the introduction of IBOC will not have a harmful impact on first adjacent channel stations. By definition, the IBOC system introduces energy in the band, and this has the potential to impact adjacent analog stations. The question for the NRSC is whether this additional energy will degrade the listening experience for the first adjacent station. The field and laboratory tests indicated any potential impact from IBOC is greatest at locations where the desired (analog-only) to undesired (IBOC) ratio (D/U) is approximately +15 dB. The field test results indicate, however, that in most cases, the analog-only performance is fairly degraded at this point. This would minimize the impact of IBOC on listeners.

Because the majority of the audio samples collected were in a speech format, iBiquity concentrated its analysis of the field test results on speech. Speech programming does not mask noise and interference as much as music programming, so the results shown indicate the worst-case scenario. As Figure 15 illustrates, at the 10 dB D/U ratio in the field, all four analog receivers had fairly degraded performance before the introduction of IBOC. Even at a 15 dB D/U ratio,[4] the Sony and Technics receivers had degraded analog performance. The introduction of IBOC at the 10 dB level had no meaningful impact because there would be few analog listeners listening to the first adjacent station. At the 15 dB level, only the Pioneer receiver had acceptable analog-only performance. The introduction of IBOC did not have a significant impact on this receiver. Although there was some potential decrease in the subjective evaluation of the Pioneer, the scores remained above the level at which the average listener would change the station or turn off the receiver. Because the Delphi, Sony and Technics receivers were already in a degraded state for analog-only reception, the introduction of IBOC did not have a meaningful impact on these receivers.



	Delphi	Pioneer	Sony	Technics	Delphi	Pioneer	Sony	Technics
Speech No IBOC	2.0	1.6	1.7	1.4	2.5	3.0	1.8	2.1
Speech IBOC	1.7	1.6	1.6	1.3	2.3	2.4	1.7	1.7

Figure 15 - Field 1st Adjacent Compatibility -- Speech Programming

The laboratory tests were structured to test the impact of IBOC at 0, +15 and +30 dB D/U ratios. At 0 dB, the analog performance was so degraded before the introduction of IBOC that the addition of the digital signal could not have any meaningful impact. At

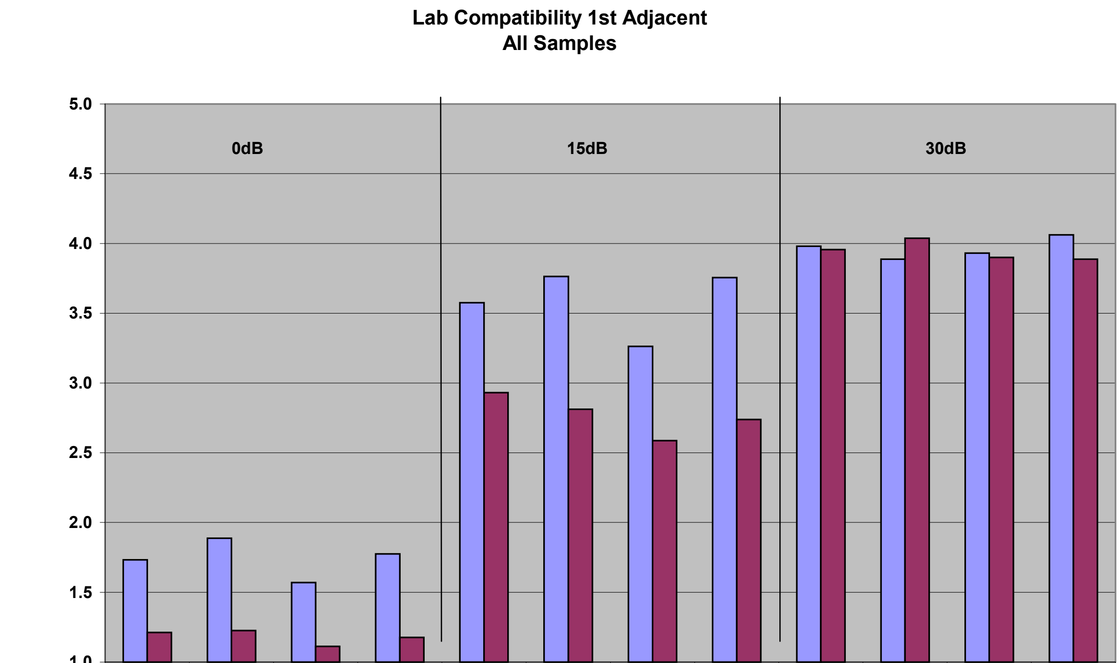
[4] The 15 dB D/U ratio actually represents an aggregation of samples at 13, 15,and 16 dB D/U. Because the field tests do not produce fully controlled conditions, it was not possible to obtain all samples at 15 dB D/U. The samples at these three levels were grouped together due to the fact that the results at these levels were comparable.

+15 dB the analog performance remains acceptable, although not good, and should highlight any potential impact from IBOC. As is summarized in Table 8 below, however, the objective lab results indicated there was an insignificant impact from the introduction of IBOC at 15 dB D/U.

Receiver	**Lower 1st Adjacent**		**Upper 1st Adjacent**	
	IBOC OFF	IBOC ON	IBOC OFF	IBOC ON
Delphi	29.2	28.7	29.5	28.4
Pioneer	27.8	27.9	28.8	26.9
Sony	25.5	27.0	29.7	25.7
Technics	27.0	29.2	30.1	26.4

Table 8 - Lab 1st Adjacent Channel Compatibility at +15 dB D/U level (dB SNR)

As Figure 16 below illustrates, the subjective evaluation confirmed the analog performance at 0 dB was so degraded that any impact from the introduction of IBOC was meaningless. Similarly, at 30 dB any potential impact from IBOC was so minimal that it did not affect listeners. The lab results indicated some potential impact at +15 dB from the introduction of IBOC. Although any potential impact would not be sufficient to cause listeners to change the station or turn off the radio, iBiquity believes the lab results somewhat overstate the impact from IBOC. The field tests indicated these analog receivers were already more degraded at +15 dB, before the introduction of IBOC, than was indicated in the lab. As was the case with the FM tests, iBiquity believes the laboratory tests do not adequately replicate field conditions and may overstate analog performance. If the lab tests had obtained more representative (and lower) analog-only performance, any potential impact from the introduction of IBOC would be much smaller and would be consistent with the overall findings from the field.



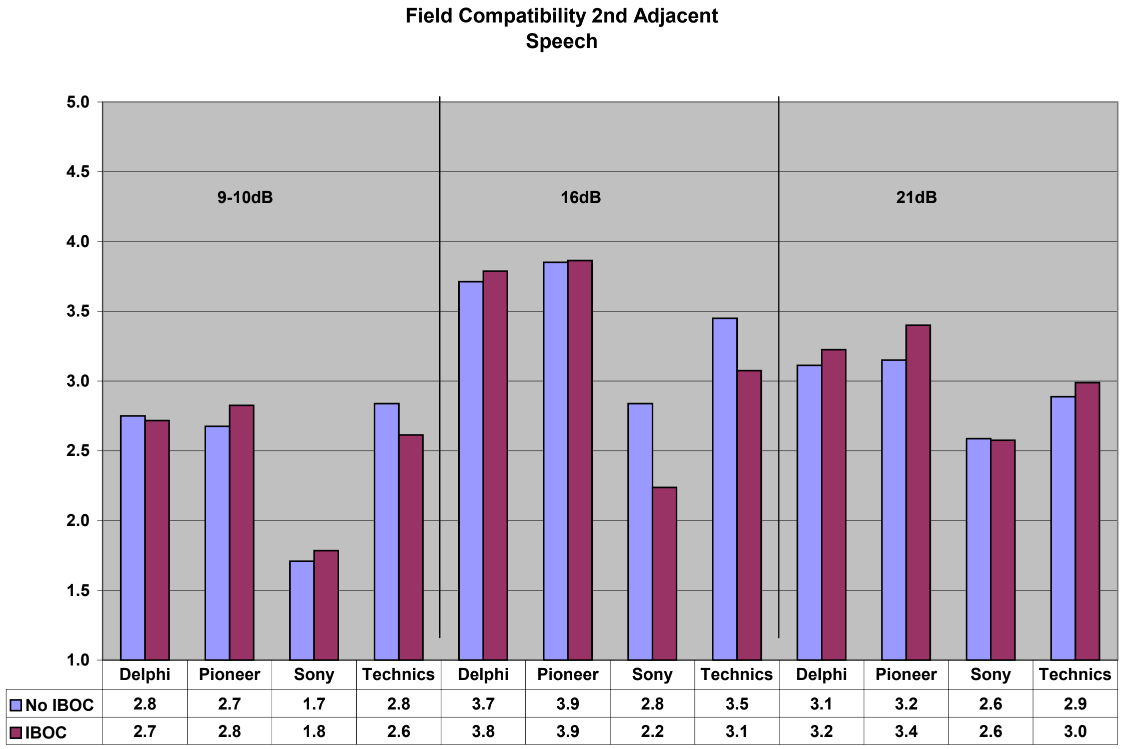
	Delphi	Pioneer	Sony	Technics	Delphi	Pioneer	Sony	Technics	Delphi	Pioneer	Sony	Technics
No IBOC	1.7	1.9	1.6	1.8	3.6	3.8	3.3	3.8	4.0	3.9	3.9	4.1
IBOC	1.2	1.2	1.1	1.2	2.9	2.8	2.6	2.7	4.0	4.0	3.9	3.9

Figure 16 - Lab First Adjacent Compatibility - All samples

The results taken in the aggregate indicate in the vast majority of cases, the introduction of IBOC should not have an impact on first adjacent analog operations. In those cases where the tests indicate a potential impact from IBOC, the analog operations are sufficiently degraded to minimize any potential IBOC impact. Moreover, in any cases where IBOC would have a potential impact, the tests indicate IBOC would not cause listeners to change the station or turn off the radio.

2. Second Adjacent Compatibility

As was the case with the host and first adjacent channel compatibility analysis, the field and laboratory results indicated the introduction of IBOC will not impact analog listening on second adjacent channel stations in the majority of cases. The field tests obtained results at three levels of second adjacent interference: +21, +16 and +9 or 10 dB D/U. As Figure 17 below illustrates, the field tests indicated no substantial impact on second adjacent channel analog listening in the vast majority of cases. Only the Sony radio exhibited any impact from the introduction of IBOC on the second adjacent channel. Again, this occurs at a point where analog-only reception is already somewhat degraded and is due to the low selectivity design of this wideband receiver. The other receivers did not change performance with the introduction of IBOC at any of these three levels.



	Delphi	Pioneer	Sony	Technics	Delphi	Pioneer	Sony	Technics	Delphi	Pioneer	Sony	Technics
No IBOC	2.8	2.7	1.7	2.8	3.7	3.9	2.8	3.5	3.1	3.2	2.6	2.9
IBOC	2.7	2.8	1.8	2.6	3.8	3.9	2.2	3.1	3.2	3.4	2.6	3.0

Figure 17 - Field Second Adjacent Compatibility -- Speech

The laboratory tests examined second adjacent compatibility at 0, +15 and +30 dB D/U. As Figure 18 below illustrates, the lab tests confirmed that there is no impact from the introduction of IBOC at low interference levels such as +30 dB. The lab results also confirmed that the Sony receiver is the only test receiver that demonstrated a potential impact from IBOC at the +15/+16 dB D/U range. The lab tests also included more severe levels of interference than were tested in the field. In the lab, tests were extended beyond the +9-10 dB D/U level to the 0 dB D/U range. At 0 dB, the lab results indicated a potentially significant impact on several of the receivers. Again, iBiquity believes these tests overstated analog performance at these interference levels. In the lab, all four receivers scored above 3.0 at 0 dB D/U. In the field, however, the tests demonstrated that analog performance was already degraded well below 3.0 at the 9-10 dB D/U ratio. iBiquity assumes the analog-only performance would have degraded further at the 0 dB level.

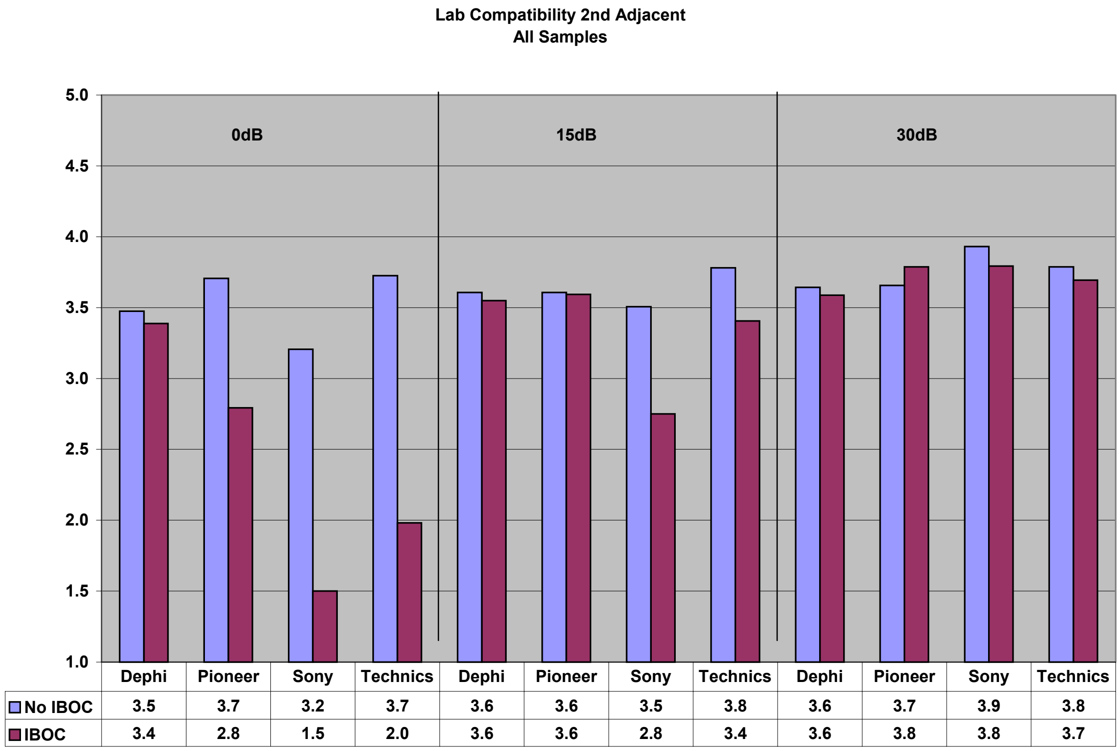


Figure 18 - Lab Second Adjacent Compatibility

3. Third Adjacent Compatibility

The introduction of IBOC on the third adjacent channel does not degrade analog performance. Table 9 illustrates that at the highest level of third adjacent channel interference included in the test program, there was no impact on any of the analog radios.

Receiver	Lower 3rd Adjacent		Upper 3rd Adjacent	
	IBOC OFF	IBOC ON	IBOC OFF	IBOC ON
Delphi	45.1	45.1	45.1	45.0
Pioneer	45.4	45.5	45.5	45.4
Sony	40.8	40.7	40.8	40.8
Technics	43.4	42.3	44.7	43.9

Table 9 - Lab 3rd Adjacent Channel Compatibility at -10 dB D/U level (dB SNR)

III. Conclusions

This report and the supporting appendices complete iBiquity's test reports to the NRSC on the benefits of IBOC DAB technology. This latest submission sets out in great detail the benefits of the AM IBOC system. The AM test results provide verification that

AM IBOC will transform AM broadcasting through dramatic improvements in AM audio quality. The IBOC system will allow AM broadcasters to deliver high quality sound that meets listener expectations for enhanced audio. This will allow AM broadcasters to diversify their program offerings and compete for listeners with high quality non-broadcast audio and entertainment offerings. This improved AM audio quality can be achieved at the same time that the IBOC system offers greatly enhanced durability in the face of adjacent channel interference and most channel impairments. Of equal importance, the tests also demonstrate that IBOC can be introduced without impacting host or adjacent channel analog operations in the vast majority of cases. Any concerns about the potential impact of IBOC are outweighed by the tremendous benefits IBOC will offer AM broadcasters. Consequently, iBiquity encourages the NRSC to provide a strong endorsement of iBiquity's AM IBOC system in order to encourage prompt regulatory action to approve IBOC and to encourage the final standardization of this technology.

LIST OF APPENDICES